Understanding and Developing Science Teachers' Pedagogical Content Knowledge

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SENSE PUBLISHERS
ROTTERDAM / TAIPEI

A C.I.P. record for this book is available from the Library of Congress.

ISBN 90-77874-23-2 Paperback
ISBN 90-77874-24-0 Hardbound

Published by: Sense Publishers,
P.O. Box 21858, 3001 AW Rotterdam, The Netherlands
http://www.sensepublishers.com

Printed on acid-free paper

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ACKNOWLEDGEMENTS

Special thanks to all of those science teachers who gave so freely of their time and ideas which were crucial to the research from which this book is based.

Jen Alabaster
Bobby Bailey
Robyn Bowering
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Deborah Corrigan
Tony Dennis
Nick Derry
Matthew Dodd
Patricia Dove
Heather Downing
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Merrin Evergreen
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Brian McKittrick
Vojtek Markus
Peter Meehan
Philippa Milroy
Ian Mitchell
Terry Mitchelmore
Peter Morgan
Wan Ng
Laura Odgers
Xenia Pappas
Wayne Reed
Catriona Scott
Gary Simpson
Barbara Sloan
Robyn Speedy
Vivienne Sullivan
Suzanne Vaughan
Andrew Walsh
Lisa Willis
Terry White
Maryanne Young

Thanks also to Claude Sironi for photographic help.

The authors are grateful for the research support made possible through funding from the Australian Research Council (Loughran ARC Large Grants 1998 – 2003).

CHAPTER ONE

TEACHING

Learning through Experience

> I had an awakening ... I had taught science in five different high schools ... believing I was a very good teacher. ... At the time I believed I had 'mastered' teaching, because I knew my science content as well as having accumulated a large repertoire of teaching strategies and hands-on activities. ... Over time, my self-perception as having 'mastered' teaching slowly dissolved. ... I progressively became aware that my teaching of high school science over 14 years was rather mundane ... Upon reflection, I realized that, as a secondary science teacher for 14 years, I knew my science content but very little about how children learn. ... Thus began my awakening about understanding the complex relationships between teaching and learning that is still evolving today. ... In retrospect ... I had such a simplistic conception of teaching during those first 14 years; it is a little embarrassing that I believed I had mastered the job. (Hoban, 2002, pp. xvi - xvii)

Teaching is complex work and like Garry Hoban (above), many teachers come to find that their initial simplistic views of teaching are confronted when the intricacies of their work becomes clearer over time. Through this process, whereby a growing understanding of teaching begins to emerge largely as a result of learning through experience, a new appreciation of one's skills and abilities compels some to move beyond the simple delivery of information.

This, however, is not as straightforward as it may sound as a strong and pervasive view of teaching is based on a transmissive model whereby prescribed content or information is delivered to students. Through this transmissive model, the approach of content "delivery" is often misrepresented as that which comprises teaching.

A transmissive view of teaching is in stark contrast to perceiving teaching as a process of enhancing learning through developing deeper understanding of content whereby teaching procedures and strategies are selected for particular reasons that are important to shaping learning in ways that are meaningful and valuable to the learner. Clearly then, there are major differences in the implications for teachers and teaching when a transmission model is contrasted to the complex model of teaching for understanding through which expertise in pedagogy is genuinely viewed as skilfully managing (and enhancing) the relationship between teaching and learning.

PROFESSIONAL LEARNING

Just as Garry Hoban experienced an awakening in relation to his views of, and subsequent approaches to teaching, for many teachers there are ongoing and subtle reminders of the mismatch between their intentions for teaching and the practice that evolves as a consequence of the dailiness of teaching (Loughran & Northfield, 1996). However, even though the distinction between delivering content and teaching for understanding may be apparent, choosing to do something about it is a completely different matter.

Unfortunately, approaches to professional learning that might encourage teachers to more readily respond to the inherent contradictions between intentions and actions in teaching are not necessarily supported at either a school or systemic level. Therefore, for those who choose to respond, the professional learning journey is often characterised by individual teachers finding themselves questioning their own practice and seeking new ways of constructing teaching and learning experiences without necessarily being supported, encouraged or rewarded for so doing.

For example, the work of Mandi Berry and Philippa Milroy (2002) demonstrates how difficult it can be to approach teaching science in ways that draw on notions of acknowledging and responding to students' prior views and purposefully addressing alternative conceptions. They set out to "teach in ways that would better facilitate students' better understanding of

science concepts; foster students' responsibility for their own learning; and, work from the position that science is a social process and that science ideas change over time" (Berry & Milroy, 2002, pp. 196 - 197).

Attempting to meet such aims obviously confronts the notion of teaching as the transmission of information. However, in attempting to address these concerns, Mandi and Philippa found it to be demanding work. There was little real support available to them within their school and, perhaps more surprisingly, even less advice and direction in the educational research literature. Therefore, they were left to work through their issues alone and to construct their teaching in new and different ways whilst simultaneously implementing such changes in their classrooms. They found themselves inventing and implementing, devising and trialling whilst also managing the day to day concerns of teaching the 'prescribed' curriculum.

What Mandi and Philippa then came to recognize was that the changes in their teaching comprised a journey, not an event. They did not teach one way at the start of their adventure and then suddenly transform their teaching overnight to be new and different teachers. They came to develop their teaching as they experimented with their practice and built new understandings of teacher and student learning. Their journey involved many false starts, much frustration, considerably more work and time and the development of new scripts that challenged their previous routines in teaching science. Their professional learning, while being personally rewarding, was not something able to be garnered from a book on curriculum reform or developed as a result of an in-service or professional development activity. Rather their professional learning was as a consequence of choosing to consistently pursue deeper levels of understanding of science with their students, and sharing, documenting and reflecting together on their efforts whilst also seeking evidence of quality learning from their students. In a real sense, they came to learn more about their skills as teachers and what to do to enhance those skills in strengthening the relationship between teaching and learning.

Moving beyond activities

One of the major changes associated with developing views of teaching that seems important in the type of shift that both Hoban (2002) and Berry and Milroy (2002) reported is linked to a recognition that teaching is much more than just having a 'kit of good activities'. Although it is important to have some routines in teaching, when teaching becomes 'routinized' elements of quality teaching e.g., engagement, enjoyment and intellectual challenge, can be dramatically diminished; or worse, absent all together. Therefore, developing helpful routines whilst not allowing teaching to become routinized is a tension that many teachers experience; a similar situation is equally pertinent in terms of learning.

It is not difficult to see how there can be a natural tendency for teachers to incorporate a range of teaching procedures (e.g., concept maps, Venn diagrams, role-play, interpretive discussion, etc.) into their practice in order to break-up the 'normal routine'. However, the use of teaching procedures simply to break up the normal routine is not the same as choosing to use a particular teaching procedure for a particular pedagogic reason. This issue goes to the heart of what it means to be an expert pedagogue: one who chooses to use a particular teaching procedure, at a particular time for a particular reason, because, through experience, that teacher has come to know how teaching in that way enhances student learning of the concept(s) under consideration. Such pedagogical reasoning is important because it is the thinking central to creating a path through complex teaching and learning situations. It is a window into the thoughtful and skilful act of practice that is responsive to the given context, i.e., there is not the assumption that the same thing works the same way all of the time. The ability to adapt, adjust and make appropriate professional judgments then is crucial to shaping the manner in which teachers teach and respond to their students' learning.

Clearly then, understanding teaching as complex, interwoven and problematic is at odds with transmissive views of teaching which inevitably trivialize and undersell the skills, knowledge and ability evident in the practice of expert teachers. The use of a range of teaching procedures to break up the normal routine, even though at times apparently effective (because of the break from the predictable routine), does not in itself mean that transmissive views of teaching do not still dominate a teacher's practice. The shift to understanding teaching as problematic, and practising it that way, involves much more than 'pulling out something different from a bag of

teaching tricks'. This point is perhaps best demonstrated through the work of PEEL (Project for Enhancing Effective Learning) teachers.

PEEL (Baird & Mitchell, 1986; Baird & Northfield, 1992; Loughran, 1999) is an example of a movement in education that directly responds to teachers' concerns about students' passive learning; which itself is partly a consequence of 'traditional' teaching. PEEL teachers view teaching as problematic and have become expert at developing teaching procedures that are the antithesis of transmissive teaching. The accumulated wisdom of practice evident in their work (shared and disseminated through a diverse range of meetings, conferences and publications) is driven by their desire to challenge students' passive learning habits in order to develop their metacognitve skills and to therefore become more active, purposeful learners. As a consequence, PEEL teachers' knowledge of teaching is such that it demonstrates well how thinking about teaching as something more than the delivery of information is a foundation to strong, ongoing professional learning.

As an experienced PEEL teacher, Rosemary Dusting (2002), offered an extensive examination of her efforts to move from *teaching as telling* to *teaching for understanding*. In so doing, she captured the essence of the challenge associated with genuinely confronting, and moving beyond, transmissive approaches to teaching.

> The method I adopted to teach Mathematics was the same as I experienced at school. ... Therefore, on my first school appointment, no option for teaching Mathematics had been demonstrated to me other than the traditional exposition model – the teacher in total control of all the knowledge. ... I suppressed memories about how certain teachers made me feel idiotic if I ventured a response that was incorrect, or how others barely even noticed whether there were students in class ... Initially I tried to perfect the exposition style and to develop a repertoire of methods to keep students quiet whilst I told them what they needed to know. Thus the type of questions I asked myself about the quality of my teaching and my students' learning tended to be restricted to blaming myself – or the students – for any perceived lack of success. I had a sense of responsibility for *making* students understand and remember. It was *my* problem. I had to show them what to do. If I did not show them properly, then they would not learn and I would have failed. (Dusting, 2002, pp. 174 – 175, emphasis in original)

In the first instance, Rosemary was confronted by the incongruity of her teaching and her expectations for students' learning, and so found the use of engaging teaching procedures as helpful in breaking her students' passive learning routines. However, over time, she also came to see the need to go beyond teaching procedures alone and to better link her teaching to her expectations for her students' learning.

> I was [now] attempting to more consistently teach for understanding ... I began to ask myself reflective questions ... [and] metacognition became important and deepened my understanding of my teaching. ... As I watched students learning this way [through PEEL procedures] I genuinely felt that I had created circumstances in which there was engagement with the task, concentration, active student involvement, risk-taking and increased interest. My teaching had shifted from me doing all the work for the students to the students now working out part of the content for themselves. They had been provided with meaningful opportunities to think and I had not taught by telling. ... My understanding of what it meant to teach students to be active learners was being developed and I valued what was happening. (Dusting, 2002, pp. 177 - 180)

In a similar way, Vivienne Sullivan (1996) came to see how the relationship between teaching and learning converged when her use of teaching procedures was carefully considered and the implications of such practice applied to not only the way she taught, but how she reflected on and planned for her teaching. With a group of others at her school, she was part of a teacher initiated examination of the use of teaching procedures in order to better understand how those procedures influenced students' learning as well as their own teaching practice. What these teachers did was to adopt an approach to examining their use of teaching procedures, discussing and writing about them using a simple but powerful formula. They considered the aim of their particular lesson, the method (i.e., teaching procedure) used to implement the aim, the observations they made of their students' learning and then evaluated the process as a whole to extract new insights about teaching and learning; they were extending their knowledge of their wisdom of practice.

In considering the use of the POE (Predict-Observe-Explain) teaching procedure in a science class, Vivienne noted that:

> The "Explain" part of the exercise was well written by about one third of the students. They tackled the conceptual errors that they had experienced in the "Predict" phase, and showed some real progress in their understanding of the experiment. ... others who had predicted inaccurately wrote explanations of their errors ... The effectiveness of the exercise as a learning tool was discussed with the students and feedback sought. It was judged by the majority of the class to have required more thought on their part than if the demonstration had just been shown to them. I feel confident that this is the case. (Sullivan, 1996, p. 32)

What is clear in the extract (above) is that the manner in which her students appeared to be thinking about the content is dramatically different from that which would normally be the case if the content were simply being told or 'delivered' to them. Even moreso, it is clear that the students were also involved in considering their own learning as they tackled their conceptual errors and explained their own inaccurate predictions; behaviours that have much more to do with constructing genuine understanding as opposed to knowing what the teacher said.

This approach to better understanding the use of teaching procedures and the articulation and development of the wisdom of practice demonstrates how understanding teaching as being problematic requires a major shift in a teacher's thinking and subsequent practice. The fundamental shift is from a view that teaching can *make* students learn, or, as Rosemary Dusting described it, "a sense of responsibility for making students understand and remember" (p. 175), to finding ways of encouraging students to accept more responsibility for their own learning.

Accepting responsibility for learning requires students to be aware of what they are doing and why, to question their own learning and, to build their knowledge by (at least) processing, synthesizing and linking the new ideas and concepts with those they already possess. In so doing, their new knowledge is a step forward in them actively developing deeper understandings of concepts/content being studied. Such acceptance is encouraged through teaching that creates meaningful opportunities for students to be engaged in constructing and restructuring their own knowledge. By the same token, it is not difficult to see that although teaching may often be misconstrued by some as the simple delivery of information, the reality is that quality learning cannot be mandated, or as Jeff Northfield explained it when reviewing a year of his teaching of Year 7, *quality learning requires learner consent* (Loughran & Northfield, 1996, p. 124).

The expert pedagogue then is one that not only chooses particular teaching procedures for particular reasons, but is also constantly developing their knowledge of practice in ways that allow them to see into teaching and learning with new eyes and to articulate the insights from so doing for others. Without doubt, such teachers have a strong grasp of the notion of professional learning through actively developing their pedagogy.

Developing pedagogy

Pedagogy is a term that is used in education in a variety of ways and to some can appear to be a buzz word or a form of jargon designed to make talk of teaching appear more sophisticated and remote from real world practice. In many instances (particularly when considered in places such as the U.S.A., Canada, U.K., and Australia) it is often used as a synonym for teaching. However, using pedagogy in that way weakens the real meaning of the term.

Drawing on the European tradition, pedagogy has more to do with understanding the relationship between teaching and learning in ways that foster children's development and growth. Van Manen (1999) eloquently describes pedagogy:

> As a practice, pedagogy describes the relational values, the personal engagement, the pedagogical climate, the total life-worlds and especially the normativity of life with children at school, at home, and in the community. And as an academic discipline, pedagogy problematizes the conditions of appropriateness of educational practices and aims to provide a knowledge base for professionals ... Central to the idea of pedagogy is the normativity of distinguishing between what is appropriate and what is less appropriate for children and what are appropriate ways of teaching and giving assistance to children and young people. (p. 14)

Therefore, in considering carefully what *developing pedagogy* might mean for teachers, it becomes immediately apparent that it entails considerably more than accumulating a 'bag of teaching tricks'. Although there is clearly a need for teachers to be familiar with, and capable of using, a range of teaching procedures, it is equally important that their use alone is not seen as an end unto itself. Hence, in developing their pedagogy, teachers are working as professionals to better understand, create and respond to the appropriate conditions through which educational practice might be enhanced and through which their professional knowledge might grow. In all of this, a concern for students and their learning is at the heart of the endeavour.

Viewed from this perspective, telling is not teaching and listening is not learning. Rather, the fluency with which teachers adopt, adapt and adjust practices to create conditions for learning matters in creating strong and meaningful links between teaching and learning that highlight the real meaning of pedagogy. And, for teachers who approach their work in this way, development of pedagogy is an ongoing aspect of their professional life. As briefly noted earlier, Jeff Northfield demonstrated such an approach in his examination of his teaching of Year 7. In so doing, he sought to learn from his experiences.

Learning from experience

Jeff Northfield, an experienced teacher, teacher educator and educational researcher, wanted to experience what it was like to be a PEEL teacher in a school. He therefore chose to stand aside from his teaching and research responsibilities at a university for a year in order to pursue his ambitions for his high school teaching. In so doing he accepted a teaching allotment that allowed him to teach the same class (Year 7, first year of high school) for science, mathematics and home group. Through the possibilities inherent in such an allotment, he was able to examine his understanding of developing pedagogy and to create possibilities for learning from experience in ways that created new insights into teaching and learning for him, and substantially shaped his professional learning.

One of the insights that Jeff gained was about the notion of 'breaking set'. He used the term to:

> ... describe the acceptance of the adjustments and changes he needed to make as a teacher as he learned to teach in a different context. Breaking set was part of his need to accept responsibility for what the class did and how they did it. ... he recognized that the students had a view of classrooms, what they had to do and how they had to do it and it was one with which they were comfortable – it was generally teacher centred. Students listened, did what was necessary, and the proceedings would come to a halt at the sound of the bell. Any departure from the 'set' could lead to a favourable response if it was an enjoyable variation from the 'set', but for the students this could not become part of the set as it did not constitute real school learning; it was viewed with some suspicion. Jeff's concern was to find the right time and level of trust to introduce activities which required thinking and encouraged acceptance of responsibility for their own learning. He found it difficult when he moved from the 'set' (expected classroom approach) ... 'breaking set' placed him in a less certain classroom environment, yet one that he was in fact seeking. (Loughran & Northfield, 1996, p. 32)

An important insight into the notion of breaking set is that it applies equally to both teacher and students. Routinized practice quickly becomes the 'set' in teaching and so 'breaking set' can create unforeseen challenges as the teacher moves from a sense of confidence in, and knowledge of particular practice, to a riskier situation characterised by uncertainty and a heightened consciousness of learning about practice through a new situation.

For students, the same obviously applies. The sense of comfort and confidence that comes with knowing the routine can quickly dissipate when the expectations for learning shift as a consequence of teachers using approaches to teaching with which students are unfamiliar. The change in expectations associated with changes in teaching and learning can therefore be quite unsettling for some and engender a response of covert resistance.

For a teacher attempting to change the expectations of, and conditions for, learning in the classroom, this resistance may be misinterpreted as students lacking the ability to work in a given way or for the quality and/or quantity of their perceived learning to be diminished as a result of 'breaking set'. However, what Jeff came to understand about this type of situation was

the need to respond appropriately to the changes in expectations so that both the teacher and the students were clear about the shift in the purpose of learning. From his experience, he recognized that students needed to understand what it felt like to be active rather than passive learners, and as a teacher, he needed to feel what it was like to persevere with teaching procedures that impacted the status-quo.

Success could only really be achieved when both the teacher and the students accepted that 'breaking set' led to positive learning outcomes, and that entailed more than simply enjoying the experience or having fun. Genuine quality learning was recognized as requiring effort and was very different from the 'busy work' that is stereo-typical of regular school learning.

Recognizing and responding appropriately to the issues associated with breaking set then becomes important in coming to terms with the ongoing effort and commitment necessary to teach (and learn) for understanding.

Jeff Northfield's journey offered him substantial opportunities for professional learning that, of themselves, could not be created or delivered through traditional professional development or in-service activities. Professional learning was about learning from, and building on, experiences and involved sustained reflection on practice, and a search to understand and construct new meaning by looking into situations from different perspectives. This ability to frame and reframe (Schön, 1983) is important for seeing teaching as problematic and for instituting ways of approaching practice that will challenge the view of teaching as telling and learning as listening. It is enmeshed in searching for multiple paths, and purposefully developing different entry points into learning through a dynamic interchange between knowledge and the process of building knowledge, as opposed to delivering static information.

WORKING FOR CHANGE

Many teachers experience the sense of unease or dissatisfaction in their teaching when they feel as though they have taught something well but their students do not seem to have learnt it as well as they initially believed. Recognizing such situations is a reminder of the problematic nature of teaching, and can also be a beginning point for teachers choosing to challenge entrenched routines. Changing practice is not easy. However, the outcomes for professional learning can be the driving and sustaining force in maintaining the effort. And, maintaining the effort appears to be linked to new ways of conceptualizing content, teaching and learning. Consequently, through professional learning the need to better articulate one's own learning about practice encourages the development of a language for sharing such knowledge. One aspect of such language can be described in terms of pedagogical content knowledge.

Similar to the term pedagogy, pedagogical content knowledge (PCK) can at first appear to be jargon. However, through linking the construct with the actual experience of exploring and examining the relationship between teaching, learning and content, PCK not only takes on a new and significant meaning, but also opens professional practice to scrutiny in ways that highlight the skills, knowledge and abilities of teachers who think about their teaching in ways that are purposeful, instructive and inextricably linked to understanding the intricacies of teaching and learning in specific content. The way they construct their teaching in response to these factors is then evident in the particularities of their PCK.

CHAPTER OVERVIEW

The intention of this chapter was to highlight a number of issues that we consider important in shaping thinking about teaching. In each case, although the points may at first appear relatively simple, on further consideration, the impact of each issue creates questions about the nature or teaching and learning and the way in which they might be played out in practice. These issues include:

- Teaching is not telling.
- Learning how to teach is about much more than collecting a set of activities to use in the classroom.
- Ideally teachers understand how students learn and recognize a number of factors that impinge on the quality of students' learning; and, on the basis of that understanding, choose and employ teaching procedures and approaches to promote quality learning.

- Teaching is problematic.
- Teachers who teach for understanding develop professional knowledge about teaching and improve their practice through reflecting on their practice and on the experiences and insights of other teachers. This commonly involves trying to think about teaching and learning from different perspectives in order to develop deeper understandings of teaching and learning situations.
- Teachers' professional knowledge requires a special language in order to facilitate better expression and sharing of ideas about teaching and learning.

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Understanding and Developing Science Teachers' Pedagogical Content Knowledge

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